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Procedia Engineering 40 (2012) 91 – 95

Procedia Engineering

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Steel Structures and Bridges 2012

Partially-encased composite thin-walled steel beams

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Abstract

The paper is focused on the partially-encased composite steel beams; the resistance of the beam with slender cross section of the wall effect of the concrete at the local stability of the beam and material savings of the steel. The material savings can be achieved by the saving in the web, which is laterally secured against buckling by the concrete. For the comparison of the partially-encased specimens, there was made a steel beam with the web of the same slenderness.

Keywords: Partially-encased beams; shear connection; concrete; static load.

1. Introduction

This contribution deals with partially-encased composite thin-walled steel beams. Due to the fact that concrete acts on the web and flange in stabilizing way, the attention is concentrated on the saving of material in the web.

One of the ways how to achieve higher parameters and particularly decrease costs of structures and their service; it is advisable to combine steel and reinforced concrete. The purpose of the combination is just to suppress the disadvantages and preserve the advantages of individual materials. The combination of these materials, some problems can occure, however the combination of steel and reinforced concrete, the consumption of steel is reduced, greater rigidity is achieved, the problems of protection against corrosion and fire are decreased, the serviceability is increased and finishing work is simplified. These advantages have an impact on the higher economy [1].

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doi:10.1016/j.proeng.2012.07.061

2. Composite steel-concrete structures

Composite steel-concrete structures belonged in the past decades between the most dynamically developed branches of supporting building structures. This development was carried out all over the world and was motivated by knowledge that composite enable utilization and combination of the advantages of reinforced concrete and steel. These advantages consist mainly in the fact that strength and toughness is the same as in case of steel and the same time is achieved rigidity like in case of reinforced concrete. Concreting of steel structures, not only anti-corrosion effect is achieved but also fire protection of steel elements. For the increase of fire resistance very significant role is played particularly by the concrete reinforcement if there is provided a sufficient thickness of its coverage by concrete. By suitable combination of elements made of reinforced concrete and of steel can be realized mixed structures that enable to achieve further savings and advantages.

2.1. Partially-encased beams

Partially-encased beams (see fig. 1) are those ones where the web of steel cross section is concreted by reinforced concrete and a shear connection between concrete and steel is created. It means the connection between concrete and steel part of partially-encased beam with such sufficient loading capacity and rigidity that it would be possible to consider this element as one supporting element. In addition, also concrete or coupled board can be part of effective cross section of coupled beam under the condition that they are connected to steel cross section by a shear connection [2].

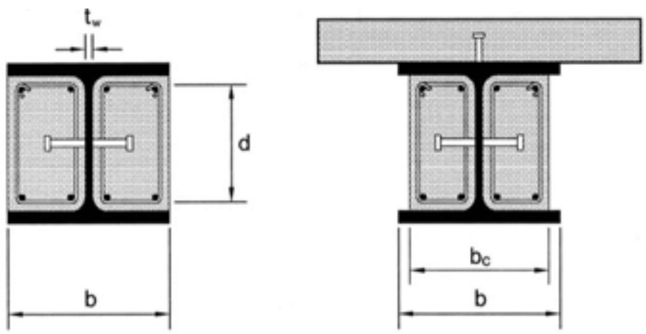

Fig.1. Typical cross-sections of partially-encased beams

2.2. Technological and structural advantages

Steel structures should be protected against the effects of weather conditions and in many cases should be provided their resistance against fire. Many parts of structures should be modified or treated. All these works are labour demanding and costly. These problems are resolved either completely or partially by concreting of steel structures. A steel structure can be designed here in a simpler way. However, it is important that the concrete mixture could be placed well and compacted. In case of reinforced concrete structures, reinforced only by concrete reinforcement are the cross sections at great loadings relatively massive and laborious for reinforcement. From the point of building technology of objects it is advisable to assemble the steel structure in advance and design for the transfer of assembly loading is gradually concreted and thus are creating composite steel-concrete structures [3].

3. Experimental and numerical research

The aim of the research is to find, theoretically and experimentally, the increment of bearing capacity of partially-encased steel beams. It is emphasized here the material saving in webs, because buckling of webs is provided by the concrete part. It is a case of beams with a web of category 4. The proper production and testing will consist of three kinds of samples, three pieces from each type.

The third type of samples serves for comparison between samples of partially concreted beams with two types of coupling and steel sample with transverse reinforcements in thirds of span, it means at places of supports and in places of loading (see fig. 2).

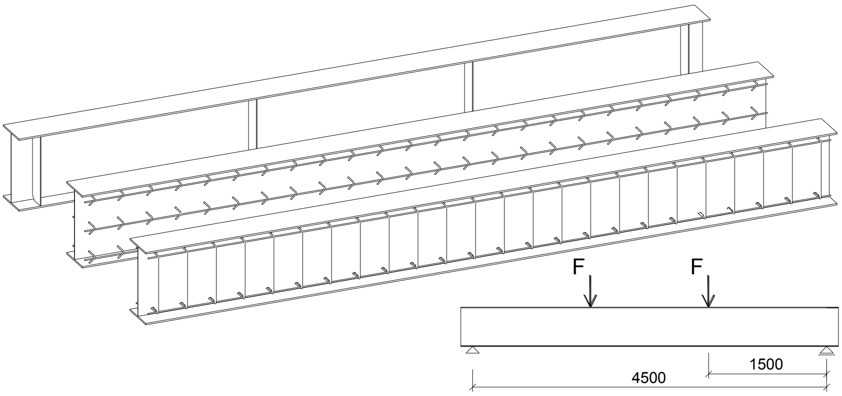

Fig.2. Kinds of samples

3.1. Experimental tests of steel beams

Before the proper testing of samples, there were measured its actual dimensions, thickness of sheets and initial deformations. The simply supported steel beam with transverse reinforcements (see fig. 3) was loaded by two hydraulic presses. The power was transferred into them after certain, in advance determined steps. At certain spots the stresses were recorded by gauges and deformation measured by induction sensors. The proper test was completed by buckling of the web at one of lateral fields and inability of the sample to transfer further loading. It was confirmed the presumption of total disruption [4].

Fig.3. Experimental test

3.2. Theoretical analysis - ANSYS

Based on the application of existing software, an adequate theoretical model (see fig. 4) can be created, suitable for numeric simulation of the acting examined structures.

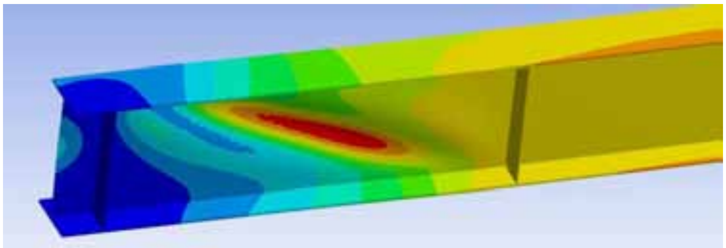

Fig.4. Theoretical model of steel beam - ANSYS

Due to verification there was created a FEM model following from experimental measurements. The model was created in a software interface ANSYS - Workbench. The shape of tensile stresses and buckling of the web illustrated in fig. 4 corresponds with the experiment, shown in the previous figure 3. Obtained results of load – deflection response are shown in next figure 5.

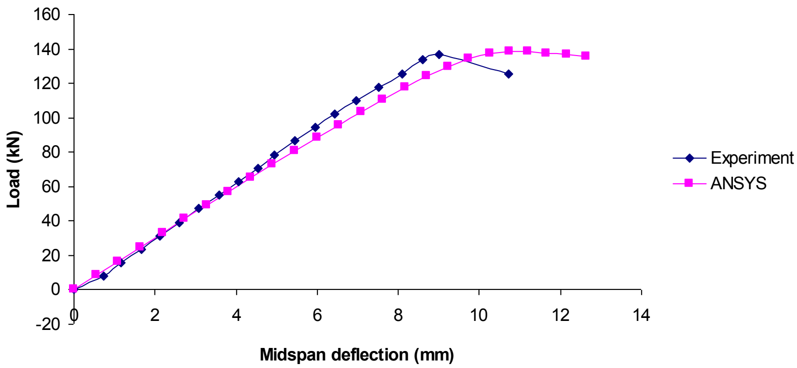

Fig.5. Load–deflection response of the steel beam

3.3. Partially-encased beams

Concreted beams (see fig. 6) are the next part in the experimental research of partially-encased steel beams. Both parts of the beam are concreted separately. The sufficient time interval between concreting works is observed. The compressive strength of concrete is determined by the testing of cubes, cylinders and beams. The procedure of the test samples will be similar to the preceding type of samples.

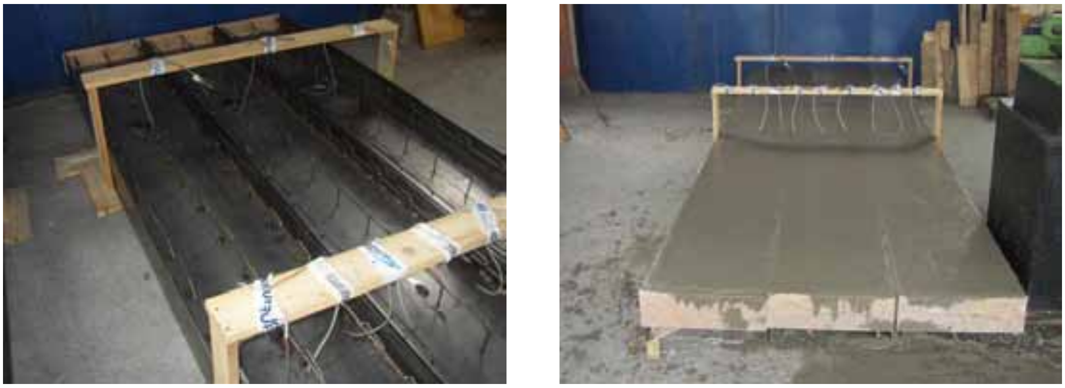

Fig.6. Partially-encased beams

4. Conclusion

The main task is to gain knowledge about the resistance of beams with slender cross section of web, effect of concrete on local stability of the beam and particularly on the achievement of steel saving. It is possible to achieve a saving by concreting in beam's web that is laterally secured against buckling.

Acknowledgements

The research was funded by the project ITMS "26220220124": "Research into Filler-Beam Deck Bridges with Encased Beams of Modified Sections".

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